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ORIGINAL RESEARCH PAPER

QUANTIFICATION OF THE POLLUTION GENERATED BY THE LEACHATE OF THE MOHAMMEDIA-BENSLIMANE LANDFILL

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Abstract: This work aims to assess the pollution generated by the leachate discharges produced at the landfill, which receives the waste collected in the towns of Mohammedia and Benslimane. Indeed, leachate discharges are a major source of contamination for the environment. Indeed, the leachate diagnosis allows on the one hand to estimate the pollutant load of the parameters (BOD5 - Biological oxygen demand, COD - Chemical oxygen demand, TSS - Total suspended solids) and on the other hand to prevent the biodegradability of the organic matter while determining the age of the leachate. This will then allow us to think about the technique that can be used to reduce pollution. The average leachate production is 146.84 m^3 per day, the physico-chemical analyses carried out have shown high concentrations for chlorides, ammoniums, COD and BOD5 respectively of 6957.65, 4203.2, 37267.5 and 19000 $mg \cdot L^{-1}$. The calculated pollutant loads exceed Moroccan standards in minerals composing the leachates, such as chlorides, nitrates, ammoniums, COD and BOD5 with concentrations respectively of 1,021.66, 8.18, 617.21, 5,472.4, 2.8 $kg \cdot d^{-1}$.

Keywords: *landfill, leachate, pollution, pollutant load, waste*

INTRODUCTION

With the socio-economic development and population growth in Morocco, consumption is becoming more and more important; therefore, the production of waste continues to increase, generating enormous risks for the environment and the health of the population [1, 2]. Waste production in Morocco is of the order of 6.9 million tons per year, which 5.5 in urban areas, with production ratio of 0.76 kg / inhabitant / day [3] and their composition is very complex and heterogeneous which makes their treatment and management difficult. The landfill of the municipality of Mohammedia-Benslimane receives more than 500 tons per day of waste this quantity is almost the same for the city of Meknes [4]. The city of fez records a quantity of production of 800 tons/day [5] while the city of Essaouira showed a daily productivity of waste of the order of 72 tons/day [6].

Leachate is a black or brown, foul smelling liquid produced during landfilling, composting, incineration, treating municipal solid waste (MSW). It contains a large amount of organic matter, inorganic salts, ammoniacal nitrogen, and metal ions in leachate [7]. Leachate has been identified as a potential source of soil contamination, ground water and surface water, as it can percolate through the soil, causing pollution of the watercourse and the water table, if they are not properly collected, processed and eliminated in complete safety.

The leachates produced in large quantities are heavily loaded with organic pollutants resulting in particular from fermentation reactions, the water contained in the waste and the percolation of rainwater through the buried waste; they are toxic effluents [8]. Because of their often-high pollutant load, the leachate must undergo a purification treatment before being discharged into the natural environment because it greatly exceeds the discharge standards imposed and represented in Table 1 by [9].

Our work is interested in the study of the pollution generated by the Mohammedia-Benslimane landfill in order to evaluate the impact of the leachate produced on the environment through:

- The characterization of the leachate
- The calculation of the polluting loads

MATERIALS AND METHODS

Study site

The leachate samples were collected from the Mohammedia-Benslimane landfill. The landfill is located about 7 km from the center of Beni yekhlef. The area of the landfill covers 47 ha and concerns the following municipalities: Mohammedia, Beni Yakhlef, Echellalate, Benslimane, Bouznika and Mansouria, with a population of 409,000 (Figure 1).

Table 1. *General Rejection Limit Values applicable to spills from waste (Discharge limit values to be respected by the spills - Pollution standards, 2014)*

Parameters	**General Rejection limit values in the waters superficial or underground**	**Dated of effect**
Temperature [°C]	30	January 2018
*p*H	5.5-9.5	
MSS [$mg\cdot L^{-1}$]	100	
Kjeldhal nitrogen [$mg\cdot L^{-1}$]	40	
Total phosphorus [$mg\cdot L^{-1}$]	15	
COD [$mg\cdot L^{-1}$]	500	
BOD5 [$mg\cdot L^{-1}$]	100	
Active chlorine (Cl_2) [$mg\cdot L^{-1}$]	0.2	
Chlorine dioxide (ClO_2) [$mg\cdot L^{-1}$]	0.05	
Aluminum (Al) [$mg\cdot L^{-1}$]	10	
Detergents (anionic, cationic and ionic) [$mg\cdot L^{-1}$]	3	
Electrical conductivity [$\mu S\cdot cm^{-1}$]	2700	
Salmonella / 5000 [mL]	Absence	
Cholera vibrios / 5000 [mL]	Absence	
Free cyanides (CN^-) [$mg\cdot L^{-1}$]	0.5	
Sulfates (SO_4^{2-}) [$mg\cdot L^{-1}$]	600	
Free sulfides (S^{2-}) [$mg\cdot L^{-1}$]	1	
Fluorine (F^-) [$mg\cdot L^{-1}$]	20	
Phenol index [$mg\cdot L^{-1}$]	0.5	
Hydrocarbons by Infra-red [$mg\cdot L^{-1}$]	15	
Oils and fats [$mg\cdot L^{-1}$]	30	
Antimony (Sb) [$mg\cdot L^{-1}$]	0.3	

Figure 1. *Site of the Mohammedia-Benslimane landfill*

Leachate sampling

At the study site, grab samples were collected weekly for one day at a rate of 2 $L \cdot h^{-1}$ for 8 hours to monitor leachate from the Mohammedia-Benslimane landfill. Leachate samples were collected in uncontaminated polyethylene bottles, labeled with the date of collection and the name of the sample, and transported to the laboratory at 4 °C.

Analytical Methods

The main physico-chemical parameters analyzed are: turbidity (turb), electrical conductivity (EC), dissolved oxygen (dissolved O_2), *p*H, chloride concentrations (Cl^-), total hardness TH, bicarbonates TA and TAC, chemical oxygen demand (COD), nitrite, nitrate and ammonium were determined by volumetry. Biological oxygen demand (BOD5) was measured by a BOD meter. Total nitrogen (TN) was estimated using the Kjeldhal method.

All samples were analyzed for physico-chemical variables according to the procedure established in the standard method of the French Standards Association (FSA), Association Française de Normalisation (AFNOR) [10].

*p*H was measured using an "Accumet Basic AB15 *p*H meter". Electrical conductivity was measured by the electrometric method, which is based on the measurement of the capacity of ions to transport the electrical current. This passage of electric current is carried out by the migration of the ions in a field produced by an alternating current. The measurement was performed using a conductivity meter (intelligent Conductivity *p*H meter YK-2001PH) according to the AFNOR standard 1994 [10].

Chemical oxygen demand (COD) was determined using the open reflux method (5220-B) according to the AFNOR standard 1994 [10]. The oxidation of the organic matter is carried out by sulphuric acid, silver sulphate and mercury sulphate acid. The sample was placed under reflux in a strongly acidic solution with a known excess of potassium dichromate. After 2 hours of digestion, the remaining potassium dichromate, which was not reduced, was titrated with ferrous ammonium sulphate. The Mohr salt determined the excess of potassium dichromate, according AFNOR standard 1994 [10].

Biological oxygen demand was evaluated by the respirometric method known as manometric, which automatically monitors the evolution of the BOD5 during the oxidation of organic matter. The method consists of filling a sample in hermetically sealed bottles of an appropriate size and incubating them at a determined temperature (20 °C) for 5 days, according to the AFNOR standard 1994 [10].

The determination of suspended matter was carried out by the centrifugation method of the AFNOR standard 1994 [10].

Phenolic compounds were determined by the colorimetric method using the Folin-Ciocalteu reagent. The determination of nitrate in the sample was carried out by the spectrometric method in the presence of sulfosalicylic acid according to AFNOR standard 1994 [10].

The determination of total phosphorus was carried out by the reaction of ammonium molybdate and potassium antimony tartrate with orthophosphate leads to the formation of phosphomolybdic acid in the sample. The latter forms an intense blue complex with ascorbic acid which can be determined by spectrometry at wavelengths of 700 and 880 nm according AFNOR standard 1994 [10].

The determination of ammoniacal nitrogen was carried out by the spectrophotometric method using indophenol blue according to the AFNOR standard 1994 [10].
The determination of the total suspended solids (TSS) in the effluents is carried out by the centrifugation method according to the AFNOR standard 1994 [10]. A volume of 40 mL of the sample is put in a glass tube and is subject to centrifugation at 5500 rpm for 15 min. The centrifuge used is a Model P Selecta Medifriger.
Chlorides were measured by the Mohr method by titration of chloride ions. It consists of a silver determination of chloride ions by silver nitrate in the presence of sodium chromate. The latter is the colored indicator which reacts at the end of the dosage to form the silver chromate, appearing as a brick-red precipitate according to the AFNOR standard 1994 [10].

RESULTS AND DISCUSSION

Despite the type, method of operation and treatment of waste and liquid discharges (leachate), leachate is a source of pollution, of soil, surface water and groundwater.
In order to assess the impacts of leachate on the environment, it is necessary to characterize the leachate generated from the different types of waste. Table 2 presents the monthly averages of COD, BOD5, *p*H, EC, TSS, ammonium, nitrates, phenols and phosphorus in the leachate produced by the Mohammedia-Benslimane landfill.

Table 2. *Physico-chemical composition of the leachates of the Mohammedia-Benslimane landfill*

Parameters \ Campaigns	C1	C2	C3	C4	Average
*p*H	7.62	8.15	7.56	8.29	7.91
EC [$mS·cm^{-1}$]	48.4	43.8	33.5	40.7	41.60
COD [$mg·L^{-1}$]	38600	36740	42010	31720	37267.5
BOD5 [$mg·L^{-1}$]	24000	19000	23000	10000	19000
TSS [$mg·L^{-1}$]	4620	5080	8880	4300	5720
NO_3^- [$mg·L^{-1}$]	33.14	92.4	77.6	19.8	55.74
NH_4^+ [$mg·L^{-1}$]	4700	4470	4343	3300	4203.25
TKN [$mg·L^{-1}$]	5932.45	5640.84	5510.1	4775.99	5464.85
P [$mg·L^{-1}$]	34	32	64	12	35.5
Phenol [$mg·L^{-1}$]	0.11	0.10	0.13	0.18	0.13
Cl^- [$mg·L^{-1}$]	6204.27	8154.19	6381.54	7090.6	6957.65
BOD5/COD	0.62	0.52	0.55	0.32	0.50

Characterization of leachate

The concentrations of biodegradable organic matter (BOD5) in leachates are high. Indeed, they vary between 10000 and 24000 $mg·L^{-1}$, with a monthly average value of 19000 $mg·L^{-1}$. BOD5 values reduce during the sampling period. The concentrations of oxidizable organic matter (COD) are also important, with a monthly average of 37267.5 $mg·L^{-1}$. These concentrations vary between 31720 and 42010 $mg·L^{-1}$. These results show a high organic load of leachate [11] specified that the COD values obtained are between

2301 and 2750 mg·L^{-1}. It can be deduced that the leachate studied is either intermediate or stabilized. The variety of leachate characteristics has been attributed to different factors, such as the variety in the composition of the composition of solid waste, the age and hydrology of the landfill, precipitation and specific weather conditions and the humidity of the waste.

Characteristics of leachate vary based on the heterogeneous solid wastes and normally depend on the compositions of waste mixtures, geographical conditions, the age of landfills / age of deposited wastes. The composition and mineralization of the leachate are influenced by the physico-chemical environment and microbial activities in the transformation of organic and inorganic compounds [12].

During monitoring, the electrical conductivity values recorded in the leachate ranged from 33.5 to 48.4 mS·cm^{-1}. The average value during the four companions is 41.60 mS·cm^{-1}. For *p*H values range from 7.6 to 8.3 and show that it is neutral to slightly alkaline leachate. These values fall within the range of the *p*H limits of rejection in the natural environment.

Fluctuations in *p*H, COD, BOD5 and the other elements have been observed, over time, in the composition of leachate [13]. This can influence the efficiency of pollution removal as well as it can cause disturbance on the receiving environment. The age of landfill is one of the main factors that also influence the characteristics of the leachate. For an old landfill, the decomposition of the leachate from a relatively short initial aerobic period to a longer decomposition period, which consists of two phases: an acid phase and a methanogenic phase, the leachate from these separate stages contains different constituents and therefore different characteristics.

The leachates studied represent a high concentration of ammonium NH_4^+ with an average of 4203.25 mg·L^{-1}, we notice a variation in nitrate contents over time, this variation can be expressed by the biological oxidation of nitrogen (phenomenon of nitrification / denitrification).

Nitrification is a biological oxidation of ammoniacal nitrogen to nitrite and nitrate (Equation 1). It is mainly carried out by groups of aerobic chemo-autotrophic microorganisms, nitrifying bacteria that use ammonia nitrogen as the only source of energy (electron donor). Bacteria nitrifying agents are classified into two groups: the group of bacteria that oxidize nitrogen ammoniacal to nitrite (nitritantes) (Equation 2) and the group of those which oxidize the nitrite to nitrate (the nitratantes) (Equation 3). Oxidation of ammonium is generally attributed to the genus *Nitrosomonas* and the oxidation of nitrite to the genus *Nitrobacter* [14].

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2\,H^+ \quad (1)$$

$$NH_4^+ + \frac{3}{2}\,O_2 \rightarrow NO_2^- + H_2O + 2H^+ \quad (2)$$

$$NO_2^- + \frac{1}{2}\,O_2 \rightarrow NO_3^- \quad (3)$$

Silva *et al.* [15] showed that the optimal *p*H values are between 7.9 and 8.2 for nitrification. Denitrification is the process of reducing nitrate (or nitrite), molecular nitrogen (N_2) and / or nitrogen gas (NO and N_2O) (Equation 4) [14].

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2 \quad (4)$$

(denitrification; denitrifying bacteria) [14]

Biodegradability of leachates

Table 3 illustrates the variation of the parameters of COD, BOD5 and the COD / BOD5 ratio.

Table 3. *Biodegradability of leachates*

Campaigns / Elements	C1	C2	C3	C4	Average
COD [$mg \cdot L^{-1}$]	38600	36740	42010	31720	37267.5
BOD5 [$mg \cdot L^{-1}$]	24000	19000	23000	10000	19000
BOD5/COD	0.62	0.52	0.55	0.32	0.5

The ratio of biological oxygen demand (BOD5) and chemical oxygen demand (COD) is an indicator used to determine the biodegradability of leachate. Depending on the age of rejection, the BOD5 / COD ratio > 0.5 in young leachate (less than 5 years), BOD5 / COD from 0.1 to 0.5 intermediate leachate (5 to 10 years) and BOD5 / COD < 0.1 stabilized leachate (> 10 years) [16].

The BOD5 / COD ratio is often used as a reference for adequacy of biological processes for the treatment of leachate. Indeed, these processes have been revealed be very effective in removing organic matter from leachate when the BOD5 / COD ratio > 0.5 where the biodegradability is good, while a lower value results in poor removal performance. In the event of release leachate, the measurement of BOD5 can be problematic because bacterial activity could barely be affected by the presence of compounds, such as heavy metals, aromatic hydrocarbons, phenols, pesticides and inorganic salts. In addition, the oxygen consumed by bacteria during the decomposition of organic matter depends on the affinity of the bacteria themselves for the organic substances present in the leachate [17].

Depending on the stage of biological evolution and the biodegradability of leachates, there are 3 types of leachate: young, intermediate and stabilized

The study of the evolution of BOD5, COD and BOD5 / COD ratio assess the biodegradability of samples over time. The BOD5 / COD ratio goes from 0.62 to 032, which indicates a significant decrease in the biodegradability of leachate.

Statistical analysis of data with factor analysis (FA)

In order to make the data more explanatory and to study the interactions between the different parameters (variants) studied, we carried out a factor analysis with the XLSTAT software; statistical processing gave us the following results presented in Table 4 which represents the minimum, maximum, means and standard deviations of the different variants represented in the study.

Table 5 expresses the correlation matrix between the variants.

Table 4. *Descriptive statistics*

Variable	Obs.	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Average	Standard deviation
*p*H	4	0	4	7.560	8.290	7.905	0.369
EC [$mS \cdot cm^{-1}$]	4	0	4	33.500	48.400	41.600	6.258
COD [$mg \cdot L^{-1}$]	4	0	4	31720.000	42010.000	37267.500	4294.177
BOD5 [$mg \cdot L^{-1}$]	4	0	4	10 000.000	24 000.000	19000.000	6377.042
TSS [$mg \cdot L^{-1}$]	4	0	4	4300.000	8880.000	5720.000	2130.853
NO_3^- [$mg \cdot L^{-1}$]	4	0	4	19.800	92.400	55.735	34.758
NH_4^+ [$mg \cdot L^{-1}$]	4	0	4	3300.000	4700.000	4203.250	620.029
TKN [$mg \cdot L^{-1}$]	4	0	4	4775.990	5932.450	5464.845	492.002
P [$mg \cdot L^{-1}$]	4	0	4	12.000	64.000	35.500	21.440
Phenol [$mg \cdot L^{-1}$]	4	0	4	0.100	0.180	0.130	0.036
Cl^- [$mg \cdot L^{-1}$]	4	0	4	6204.270	8154.190	6957.650	884.848

Table 5. *Correlation matrix [Pearson]*

Variables	*p*H	EC	COD	DBO5	TSS	NO_3^-	NH_4^+	TKN	P	Phenol	Cl^-
*p*H	**1**	0.151	-0.901	-0.888	-0.627	-0.155	-0.688	-0.681	-0.814	0.447	0.774
EC	0.151	**1**	-0.317	0.081	-0.830	-0.334	0.313	0.414	-0.565	-0.370	0.124
COD	-0.901	-0.317	**1**	0.920	0.792	0.566	0.776	0.720	0.961	-0.629	-0.448
BOD5	-0.888	0.081	0.920	**1**	0.489	0.448	0.942	0.926	0.775	-0.808	-0.429
TSS	-0.627	-0.830	0.792	0.489	**1**	0.547	0.254	0.157	0.929	-0.131	-0.344
NO_3^-	-0.155	-0.334	0.566	0.448	0.547	**1**	0.527	0.422	0.614	-0.659	0.472
NH_4^+	-0.688	0.313	0.776	0.942	0.254	0.527	**1**	0.992	0.590	-0.953	-0.155
TKN	-0.681	0.414	0.720	0.926	0.157	0.422	0.992	**1**	0.511	-0.934	-0.199
P	-0.814	-0.565	0.961	0.775	0.929	0.614	0.590	0.511	**1**	-0.454	-0.397
Phenol	0.447	-0.370	-0.629	-0.808	-0.131	-0.659	-0.953	-0.934	-0.454	**1**	-0.150
Cl^-	0.774	0.124	-0.448	-0.429	-0.344	0.472	-0.155	-0.199	-0.397	-0.150	**1**

In Table 6 are displayed the proper values resulting from the factorial analysis. We note that with the first two factors we keep 83.373 % of the variability of the initial data to reach 100 % with the third factor.

Table 6. *Proper values*

	F1	F2	F3
Proper value	6.494	2.677	1.829
Variability [%]	59.035	24.338	16.627
Cumulative [%]	59.035	83.373	100.000

The results represented in proper values and in cumulative variabilities are illustrated in the Figure 2.

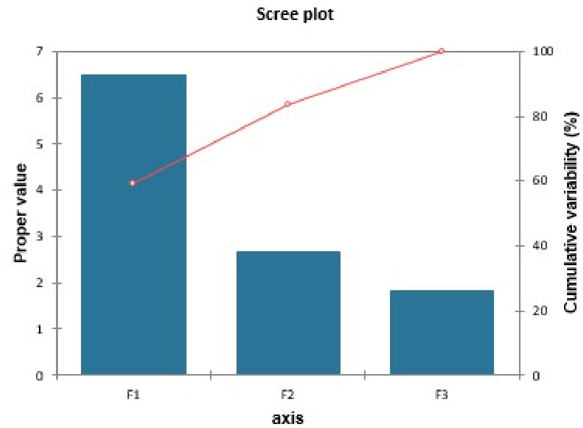

Figure 2. *Proper values and in cumulative*

Using the rotation feature in the software helps to make data analysis more obvious. The treatment of data studied after rotation gave us the results shown in Table 7 and 8.

Table 7. *Percentage of variance after Varimax rotation*

	D1	**D2**
Variability [%]	47.210	36.163
Cumulative [%]	47.210	83.373

Table 8. *Factorial coordinates after Varimax rotation*

	D1	**D2**
*p*H	-0.608	**-0.656**
EC [$mS \cdot cm^{-1}$]	0.438	**-0.846**
COD [$mg \cdot L^{-1}$]	0.681	**0.732**
BOD5 [$mg \cdot L^{-1}$]	**0.894**	0.422
TSS [$mg \cdot L^{-1}$]	0.118	**0.975**
NO_3^- [$mg \cdot L^{-1}$]	**0.474**	0.349
NH_4^+ [$mg \cdot L^{-1}$]	**0.990**	0.139
TKN [$mg \cdot L^{-1}$]	**0.995**	0.058
P [$mg \cdot L^{-1}$]	0.472	**0.875**
Phenol [$mg \cdot L^{-1}$]	**-0.964**	0.032
Cl^- [$mg \cdot L^{-1}$]	-0.096	**-0.505**

From Table 8, it can be seen that the first factor is strongly linked to BOD5, NO_3^-, NH_4^+, TKN and phenol. As for the second, it is strongly linked to *p*H, EC, COD, TSS, P and Cl^-.

The Figure 3 groups together the different parameters studied after rotation.

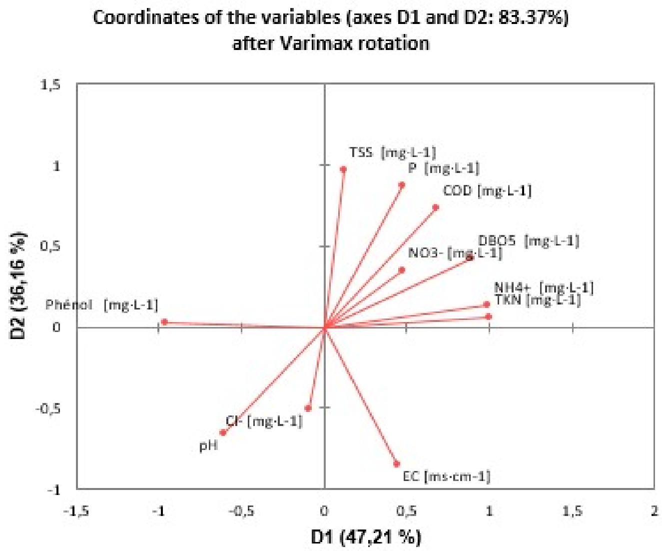

Figure 3. *Coordinates of variables*

Most of the variables (TSS, COD, BOD5, NO_3^-, NH_4^+, TKN, P) are positively linked to the D1 and D2 axes, on the other hand the *p*H and the Cl^- are negatively linked to these two axes. The Figure 4 represents the correlation between the different parameters.

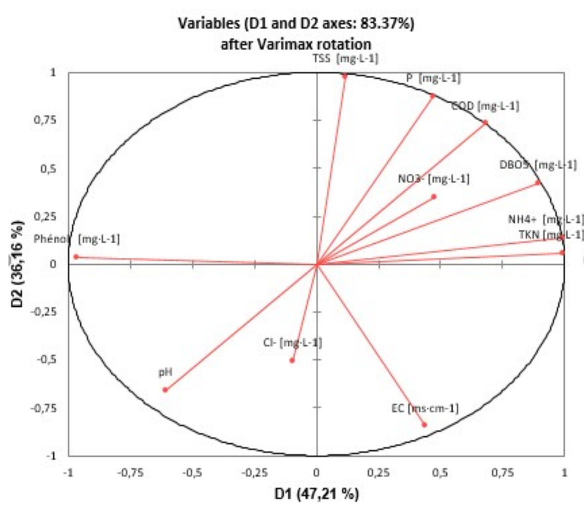

Figure 4. *Correlation between variables*

The interpretation of the results shown in Figure 4 is based primarily on the variation in angle between the variables.

- Acute angle: positively related variables
- Right angle: unrelated variables
- Obtuse angle: negatively related variables

From Figure 4 we notice that TSS, COD, BOD5, NO_3^-, NH_4^+, TKN, P are negatively related to *p*H, unlike Cl^- which is positively related to *p*H. While COD and BOD5 are positively related, both NH_4^+ and TKN are positively related.

Quantity of leachates produced

The calculation of the volume of leachate ($V_{leatchate}$) produced per day, taking into account the quantity received, was determined during the month of November 2018. Two methods were used: Leachate ratio is 0.26 $m^3 \cdot ton^{-1}$ of waste [13] (Equations 5 and 6) and 0.5 $m^3 \cdot ton^{-1}$ of waste report of World Bank:

$$V_{leatchate} = Q\ (Ton.d^{-1}) * 0.26\ (m^3\ leachate.ton^{-1}) \quad (5)$$

$$V_{leatchate} = Q\ (Ton.d^{-1}) * 0.5\ (m^3\ leachate.ton^{-1}) \quad (6)$$

The results of the volume of leachates obtained during the month of November are illustrated on the Table 9.

Table 9. *Volume of leachate produced by the 2 methods used*

Days	**Ton·d^{-1}**	**Q [m^3·d^{-1}] * 0,26 [10]**	**Q [m^3·d^{-1}] * 0,5 (bank Mondial)**
1-nov.-18	462.60	120.28	231.30
2-nov.-18	586.06	152.38	293.03
3-nov.-18	479.20	124.59	239.60
4-nov.-18	425.10	110.53	212.55
5-nov.-18	544.82	141.65	272.41
6-nov.-18	547.16	142.26	273.58
7-nov.-18	627.70	163.20	313.85
8-nov.-18	559.34	145.43	279.67
9-nov.-18	596.12	154.99	298.06
10-nov.-18	596.16	155.00	298.08
11-nov.-18	426.40	110.86	213.20
12-nov.-18	578.80	150.49	289.40
13-nov.-18	562.34	146.21	281.17
14-nov.-18	522.22	135.78	261.11
15-nov.-18	518.22	134.74	259.11
16-nov.-18	590.56	153.55	295.28
17-nov.-18	587.84	152.84	293.92
18-nov.-18	511.00	132.86	255.50
19-nov.-18	586.36	152.45	293.18
20-nov.-18	436.46	113.48	218.23
21-nov.-18	553.24	143.84	276.62
22-nov.-18	795.32	206.78	397.66
23-nov.-18	779.74	202.73	389.87
24-nov.-18	680.30	176.88	340.15
25-nov.-18	388.66	101.05	194.33
26-nov.-18	578.16	150.32	289.08
27-nov.-18	633.48	164.70	316.74
28-nov.-18	617.86	160.64	308.93
29-nov.-18	565.58	147.05	282.79
30-nov.-18	606.62	157.72	303.31
Average	564.78	**146.84**	282.39

The results obtained show that:

- The amount of waste received at the Mohammedia-Benslimane landfill varies from day to day with an average production of around 565 tones·day^{-1}. In parallel, the volume of leachate calculated by the two methods varies over time;
- The daily volume of leachate produced per day using the World Bank method is twice that determined by [13], the ratio method (0.26 m^3·ton^{-1} of waste) obtained at the Kenitra landfill [13] and 0.5 m^3·ton^{-1} (Banque Mondiale 2015).

Calculation of polluting loads

The pollutant load was estimated using the leachate ratio determined by [13] produced by the Kenitra City landfill. The retained ratio is 0.26 m^3 of leachate / ton of waste. The pollutants produced by the leatchate are shown in Table 10.

Table 10. *Calculating pollutant load for different parameters*

Parameters	Average concentration [mg·L^{-1}]	Pollutants loads [kg·d^{-1}]
COD	37267.5	5472.36
BOD5	19000	2789.96
MES	5720	839.9248
NO_3^-	55.74	8.18
NH_4^+	4203.25	617.21
NKT	5464.85	802.46
P	35.5	5.21
Phenol	0.13	0.019
Cl^-	6957.65	1021.66

The evolution of the different concentrations of pollutant loads for the parameters analyzed for the leachate are illustrated in the following (Figures 5, 6, 7, 8, 9, 10, 11 and 12).

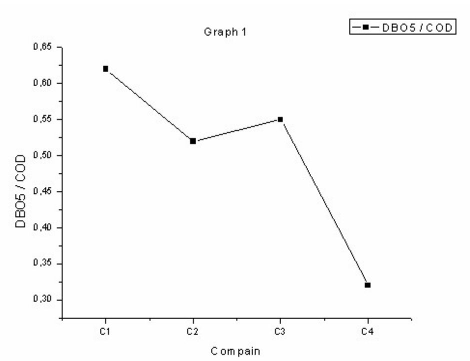

Figure 5. *Evolution of biodegradability*

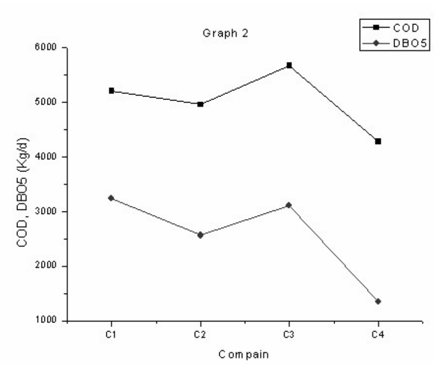

Figure 6. *Evolution of COD and BOD5*

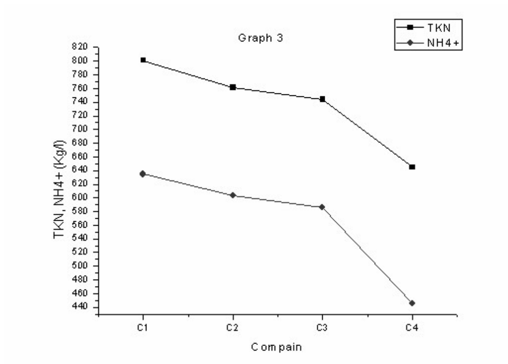

***Figure** 7. Evolution of TKN and NH_4^+*

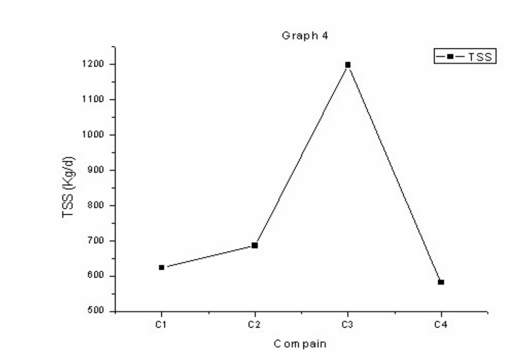

***Figure 8**. Evolution of TSS*

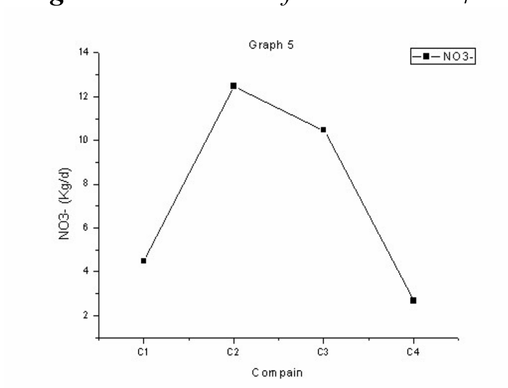

***Figure 9**. Evolution of NO_3^-*

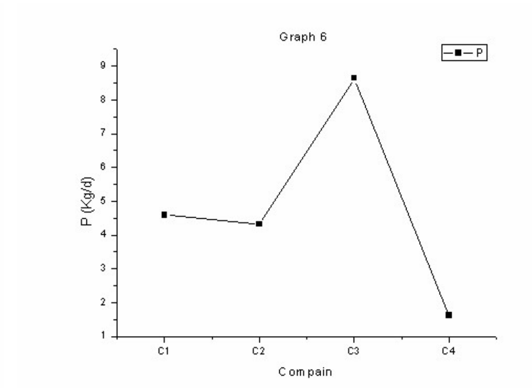

***Figure 10**. Evolution of phosphorus*

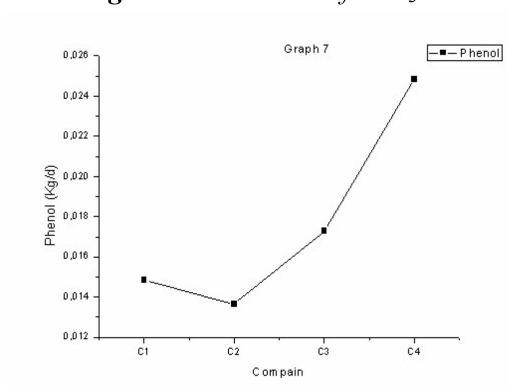

***Figure 11**. Evolution of phenol*

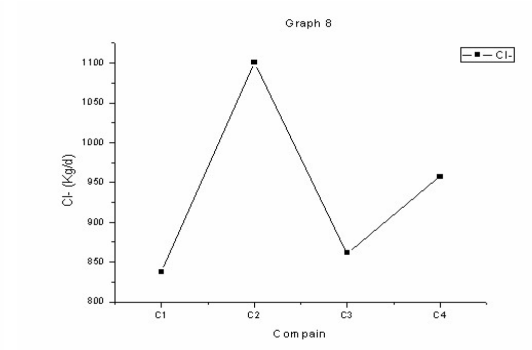

***Figure 12**. Evolution of chloride ions*

The characterization of liquid discharges from landfills makes it possible to assess their risk for the environment. We carried out sampling campaigns in order to identify the pollution generated by the leachate from the Mohammedia-Beslimane public landfill. The tables and graphs present the evolution results of the pollution produced by the leachate.

After the first aerobic degradation at the beginning of burial, the first phase of anaerobic decomposition is an acidic fermentation; the "young" percolas are rich in volatile fatty acids (VFA) which can represent up to 95 % of the total organic carbon, this acidity of the leachate makes it possible to solubilize the metals present in the waste. Over time,

complementary biological evolution consists of anaerobic digestion during which AGV is metabolized. The products resulting from this metabolization are gases (mainly CO_2 and CH_4) and stabilized molecules (fulvic and humic acids). Therefore, as it ages, a landfill will produce a leachate that is increasingly poor in AGV or small biodegradable molecules [18, 19].
The concentrations of organic matter expressed in BOD5 and COD of leachate, are important. The results of the monitoring showed a significant degradation of the organic matter during the winter period, [20] found a slight degradation of organic matter during this period that is influenced by the change in temperature.
Chofqi *et al.* [20] realized 7 sampling campaigns of the leachate coming from the landfill of the city of El Jadida city in Morocco. This study revealed that the leachate has a basic *p*H of 7.91 and contains 5472.36, 2789.96 and 617.21 $mg \cdot L^{-1}$ respectively of COD, BOD5 and NH_4^+. The authors conclude that this leachate is stabilized and not biodegradable [21, 22].
The characterization of leachate from El-Kerma's landfill (Algeria) was studied by Bennama *et al.* [22]. The authors demonstrated that it is an intermediate leachate containing 19333 $mg \cdot L^{-1}$, 3301 and 2726 $mg \cdot L^{-1}$ respectively of COD, BOD5 and ammonium. However, they recommended the treatment by adsorption on natural wood sawdust chemically activated.
The BOD5 / COD ratio indicates the degree of biodegradability and provides information on the nature of leachate biochemical transformations [22]. The degradation of organic matter is changing over time [9] by decreasing the pollutant load of the effluent in our case, the ratio BOD5 / COD indicated that the leachates taken are of intermediate type [19] and tend to stabilize.
The anaerobic fermentation is characterized by the decrease of the COD and especially of the BOD5 [20]. BOD5 can become zero over the years. This phase is also characterized by high concentration of nitrogen.
Reduction of BOD5 and COD has increased Kjeldhal nitrogen and ammonium concentrations, while nitrate concentrations in leachates remained low due to nitrification and denitrification phenomena.
The leachates analyzed have very high conductivity values and chloride concentrations. This is a characteristic common to all landfills in Morocco [20, 23, 24].

CONCLUSION

The results of this study highlight the pollution that can be generated by the Mohammedia-Benslimane landfill by producing large quantities of leachate.
The characterization of leachate and the determination of their polluting load make it possible to determine the type of leachate studied in order to define the appropriate treatment. It can also be deduced that the rejection currently goes through the biological activity stage.
The results show that the pollutant loads are high in organic and mineral matter, corresponding to the acetogenic phase : acetogenesis (BOD5 / COD = 0.5).
The leachate discharges are highly charged with ammonium ions and rich in moderately biodegradable organic matter.

The volume of leachate produced based on the World Bank is double that determined experimentally by the method of [11].
According to the statistical analysis of the studied parameters we notice that they are strongly correlated between them and possess the characteristic of the dependence in behavior by evolving in the time.

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